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Site Preparation Alternatives in the Wet, Cold ESSF: Results from Sicamous Creek

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Summary

Site preparation decisions for high-elevation sites are becoming more complex, with increasing concern over costs, management responsibilities for values beyond tree regeneration, use of alternative harvest systems, and natural regeneration. The Sicamous Creek silvicultural systems project includes studies of the response of many forest values to four site preparation treatments—mounding, burning, scalping, and no treatment—within five types of harvest treatments. Initial results are presented for planted and natural regeneration of both tree species, soil properties, vegetation, and response of plant and animal components of biodiversity.

Burning is favoured for planted spruce, while mounding is favoured for subalpine fir. Exposed mineral soil is required for abundant natural regeneration. Soil chemistry is affected less by site preparation than by harvesting effects. However, mounding can substantially reduce vegetation cover and soft woody debris, which leads to declines in animals that use these habitat features, such as red-backed voles. The damage results mainly from the excavator, and might be reduced by careful management of the mounding operation.

Burning, scalping, and to a lesser extent mounding lead to large increases in species associated with disturbances, such as fireweed, small-flowered woodrush, and invasive ants. These changes will affect many other aspects of the ecosystem, and are likely to persist for a long period in the slow-growing ESSF. Burning, however, also provides a unique habitat for organisms that are well adapted to recently burned sites.

The findings suggest that where an important management goal is to retain and rapidly recover environmental values of older forests, planting without any site preparation will meet basic regeneration objectives without incurring the negative effects of site preparation.

Using a variety of site preparation options remains key, as it does for any other aspect of silvicultural practice that affects many resource values.

introduction

Historical difficulties in regenerating wet, cold, high-elevation Engelmann spruce – subalpine fir (ESSF) forests have led to operational interest in trials of different silvicultural systems in this zone, including alternatives to standard large clearcuts and site preparation techniques. Currently, the main silvicultural goal of site preparation in the ESSF is to provide microsites that are suitable for good survival and growth of planted Engelmann spruce, the preferred timber species.

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Secondary goals include providing tree planter access and reducing the fire hazard associated with logging slash. Because site preparation is expensive, meeting these objectives at minimal cost is operationally critical.

Site preparation techniques have changed dramatically in the wet ESSF since widespread logging began in this zone in the 1970s. Broadcast burning of slash in the fall was the dominant technique until 10 years ago. Today very little burning is practised. Various mechanical treatments have also been tried over the years, including windrowing, brush-blading, dip and dive, and disc-trenching.

Mounding with an excavator is currently the site preparation technique of choice in about 50% of the cutblocks located in the southern interior portions of the ESSF. In this technique, the excavator bucket is used first to remove woody debris from the planting spot, and then to dig into the soil and pull forward a mound of mineral soil. This mound is deposited on an overturned patch of litter, humus, and vegetation. Mounds are believed to provide better microclimatic conditions for early spruce survival and growth, while burying forest floor material that can provide nutrients for future growth. However, mounding is slow and has a substantial cost in the ESSF— $700–900 per hectare.

The evolution of site preparation techniques, combined with better nursery stock, new stock types, and rapid planting following logging, has greatly improved regeneration success for spruce in high-elevation sites. Nevertheless, several recent changes are making site preparation decisions more challenging for foresters. The high cost of site preparation, for example, is leading to questions about how much effort is really needed to meet silvicultural objectives. At the same time, expectations for forestry have expanded well beyond the

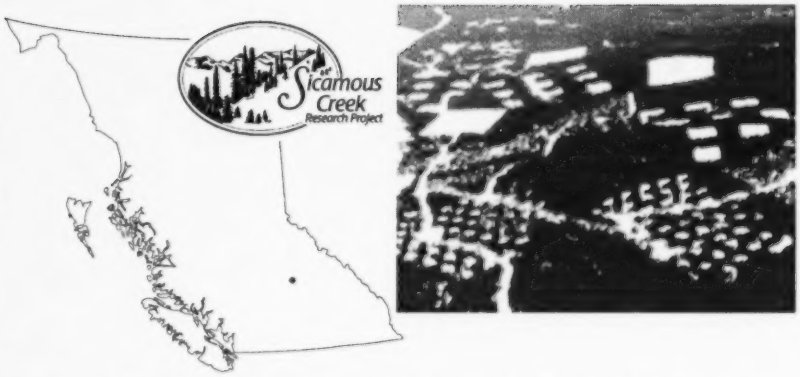

FIGURE 1 *Location and aerial photograph of the Sicamous Creek silvicultural systems research project.*

successful regeneration of future crop trees. Soil conservation, the maintenance of long-term productivity, and the maintenance of biological diversity are all now management concerns and professional obligations of foresters. Site preparation can have major effects on meeting these objectives—effects about which more information is needed.

This diversity of concerns is encouraging interest in the use of alternative harvest systems such as small openings and partial cuts and the influence of retained patches on the development and growth of regeneration in openings. However, information on the effectiveness of different site preparation options under these harvest systems is sparse, as is information on the basic silvicultural goal of regenerating crop trees.

Silvicultural systems research sites are one way this lack of information is being remedied in British Columbia. The Sicamous Creek project in the ESSF forest type is one of the largest of these research sites, with over 40 researchers working on a wide range of forest components. Its primary focus is on harvest treatments and edge effects (initial results of that work are summarized in Huggard and Vyse 2002a, 2002b). An important secondary focus, however, is on the effect of different site preparation options within each harvest treatment.

This report presents the initial results of studies in the site preparation treatments at Sicamous Creek. The aim is to provide some guidance for operational decision-making about high-elevation site preparation under different harvest treatments, and to contribute to current knowledge about the effects of site preparation on many forest components.

Methods

Study area and site preparation treatments

The Sicamous Creek silvicultural systems site is located in a 350-year-old stand in the ESSFwc2, 15 km southeast of Sicamous, B.C. (see Figure 1). The site has fifteen 30-ha units, with three replicates of five harvest treatments: 10-ha clearcuts, arrays of 1-ha openings, arrays of 0.1-ha patch cuts, individual tree selection, and an uncut control.

Four site preparation treatments were implemented in 30 × 30 m subplots within each of the 15 replicate units (see Figure 2):

1. **Mounding**, in which an excavator was used to produce mounds approximately 1 × 2 m and 30 cm high, spaced 3 m apart. This is the most common operational treatment used on these sites.
2. **Burning**, in which drip torches were used to ignite moderate-to low-intensity controlled fires in late summer. These fires reduced forest floor litter, eliminated most above-surface ground vegetation, and scorched coarse woody debris (CWD) and the lower stems of trees, but did not consume all fuel in the plots.
3. **Scalping**, in which an excavator was used to remove almost all forest floor organic material, including CWD. This extreme treatment produced microsites similar to those created by older forms of site preparation such as brush-blading, but was also intended to initiate a long-term experiment into the effects of reducing forest-floor organic materials.
4. **No treatment** (no site preparation disturbance).

Mesic sites, which dominate the Sicamous trial area, were chosen for all plots, where possible, in order to control some of the variation caused by site differences. All site preparation treatments were implemented in all harvest types, including individual tree selection and uncut treatments. Some of these combinations are clearly not intended as operational options, but were conducted at the research site to further understanding of ecological processes. In particular, the fully nested design helps to distinguish the effects of harvesting and site preparation, and interactions of the two.

Variables measured

Performance of planted seedlings

Regeneration studies measured 6-year survival, root-collar diameter, and height of approximately 100 2+0 summer-planted seedlings (50% Engelmann spruce and 50% subalpine fir) in each site preparation plot.

Operational planting in the no-treatment and burned site preparation plots involved boot-screefing of some forest floor at the planting site. Trees were planted at a set spacing (2–3 m), not just where there were good planting sites. In the mounding treatment, seedlings were usually planted on, or close to, the top of the mound. Occasionally, two seedlings were planted on each mound.

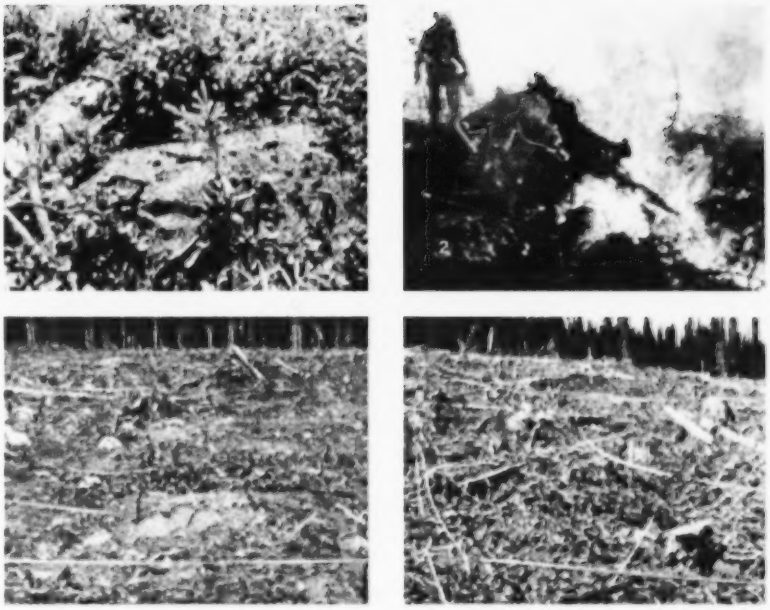

FIGURE 2 *Examples of site preparation treatments at Sicamous Creek: 1) example of a planted mound; 2) burning in progress; 3) result of scalping; 4) no site preparation.*

Natural regeneration

Several studies examined natural regeneration, because of increasing interest prompted by ecological concerns and certification standards. Natural ingress of each species was measured in five 4 × 4 m vegetation plots in each site preparation unit. As well, seed germination rates and 2-year survival for both species were measured in six small plots (each planted with 50 seeds) per site preparation unit. Some subplots were protected by fine mesh while others were left unprotected. This enabled the measurement of seed predation. How much advanced regeneration was retained for wildlife habitat structure was also measured in 0.01-ha plots in each site preparation unit. Additional work at the site measured seedfall and germination success on different substrates.

Soil chemistry and temperature

Preserving short-term nutrients for seedlings and maintaining long-term soil productivity are concerns with intensive site preparation. Initial soil studies measured the 5-year response of soil chemistry to each site preparation treatment in openings and uncut forest, and established a baseline for projections of long-term changes. Measurements were made of total nitrogen, nitrate, ammonium, carbon,

and many nutrient elements in forest floor and mineral soil. Because cold soils are also a potential limitation on tree growth in the ESSF, soil temperatures were measured in August at 15-cm depth, and in September at 1- and 15-cm depths.

Vegetation

Non-crop vegetation can compete with slow-growing tree seedlings and interfere with long-term site productivity and succession. At the same time, vegetation is necessary in providing critical wildlife habitat, it provides a broad indication of ground disturbance, and plants and lichens are important components of biodiversity.

So that the effects of vegetation could be studied, five 4 × 4 m vegetation plots were surveyed in each site preparation unit in several years following treatment. Total cover of shrubs, herbs, and mosses was recorded, along with cover, height, and percent flowering of each species. Lichen species were also recorded in four abundance classes. Additional comparisons of vegetation and regeneration were made using large numbers of paired 2 × 4 m screefed and undisturbed plots along transects across the edges of openings and uncut forest.

Coarse woody debris and animals

Coarse woody debris is another important wildlife habitat element that is affected by site preparation. In each site preparation plot, CWD volume was recorded using 30-m triangular intercept transects. Animal surveys, limited to small species by the 30 × 30 m scale of the site preparation plots, included the use of pitfall traps to sample soil microarthropods in mineral soil and the forest floor (with species-level sorting) and terrestrial invertebrates (with identification to Family or Order level). The same pitfall traps also provided a sample of shrews and juvenile rodents, especially red-backed voles.

Summarizing the results

For the purposes of this report, results for each site preparation treatment were averaged across all harvest treatments, unless distinctly different patterns of site preparation responses were revealed. Averaging harvest treatments does not mean there were no absolute differences between the harvest treatments—it just reflects the decision made here to focus on the pattern of site preparation effects.

Effects of the overall harvest treatments at Sicamous Creek have been summarized and interpreted in a previous Extension Note (Huggard and Vyse 2002a).

To facilitate comparisons of site preparation treatments, responses for each variable were colour-coded, with green representing the best treatment(s) for a variable, yellow a moderately worse value, orange a substantially worse result, and red a potentially large problem. Colour choice was based on the primary researcher's interpretations of the biological significance of the differences between treatments. For some variables, such as indicators of site disturbance, a higher value is worse than a lower one. However, evaluation of "better" or "worse" is sometimes ambiguous. More mineralized nitrogen, for example, can be beneficial as a tree nutrient in the short term, but may lead to loss of nutrients from leaching in the long term.

Results and Discussion

Implementation

All site preparation treatments were implemented as intended, with the partial exception of the burns in the individual tree selection and uncut harvest treatments. These burns had to be very light because of safety concerns. In general, fuel consumed in the burns increased with the size of opening. Given that initial fuel conditions and fire severity indices were the same for the different openings, it can be assumed that the increasing severity of the burns in larger openings must reflect more suitable microclimates for burning. The estimated costs of operational implementation of the treatments are $700–900 per ha for mounding and $500–2000 per ha for burning.

Performance of planted seedlings

Harvested treatments

Planted seedlings of both species performed better in openings than in individual tree selection units, but the relative effects of the site preparation treatments were similar in all harvested treatments. Survival of Engelmann spruce was higher in all site preparation treatments compared to that of seedlings planted in the no-treatment areas, with highest survival occurring in the scalped plots (Table 1A). Diameter growth was somewhat higher in burns than in the other two site preparation treatments, and height growth was substantially greater. Survival of subalpine fir was similarly much lower in the no-treatment units, and somewhat lower in the burns compared to the treatments that preserved more mineral soil. Diameter growth was also slightly lower in the burns, but height growth was greatest in the burns and only slightly lower in the mounds.

Overall, the burns were more successful for planted spruce regeneration, while the mounding was better for regenerating subalpine fir, though the differences between treatments were small. Spruce survived and grew better than subalpine fir in all treatments. According to Feller (unpublished report, 1994) fall burns are better than spring burns or mechanical site preparation for promoting survival and growth of both species in similar sites near Clearwater, B.C.

Uncut treatments

Responses to site preparation were different in the experimental treat-

TABLE 1 *Performance of seedlings (Engelmann spruce and subalpine fir) 6 years after planting, by site preparation treatment*

A. Harvested treatments

Species	Variable	No treatment	Mound	Burn	Scalp
Spruce	Survival (%)	0.64	0.75	0.73	0.79
	Diameter (mm)	9.2	12.3	13.5	12.6
	Height (cm)	52.3	58.8	71.2	59.9
Subalpine fir	Survival (%)	0.46	0.67	0.61	0.70
	Diameter (mm)	7.1	10.0	9.2	9.6
	Height (cm)	31.4	37.3	39.6	34.9

B. Uncut treatments

Species	Variable	No treatment	Mound	Burn	Scalp
Spruce	Survival (%)	0.58	0.64	0.44	0.42
	Diameter (mm)	7.0	7.1	7.9	6.1
	Height (cm)	41.3	38.8	42.8	34.1
Subalpine fir	Survival (%)	0.23	0.49	0.25	0.34
	Diameter (mm)	6.8	6.7	6.3	5.6
	Height (cm)	21.0	24.5	24.4	19.6

Source: Vyse and Ferguson (unpublished data, 2003)

ments on the uncut harvest blocks (Table 1B). For spruce, burning and scalping substantially reduced survival compared to mounded or undisturbed sites. Growth of surviving seedlings was best in burns, but comparable in mounded and undisturbed sites. For subalpine fir, survival under canopy was much higher in mounded sites, which also showed relatively good growth. Spruce survived and grew better than subalpine fir in all treatments.

These results suggest that different processes affect seedlings under canopy. Choosing suitable planting sites without site preparation might be considered in denser partial retention, or adjacent to retained patches in variable retention or small patch-cut systems. However, exposure of mineral soil would be needed to exploit natural regeneration from the abundant seedfall in these harvest types.

TABLE 2 *Advanced and natural regeneration in Engelmann spruce and subalpine fir, by site preparation treatment*

Species	Variable	No treatment	Mound	Burn	Scalp
Both	Advanced regen.(/ha)	130	130	20	10
Spruce	Nat. germinants (/m^2)	0.3	8.4*	1.3	8.4*
	Germinants from seed (%)	0.7	9.0*	2.5	9.0*
	2-yr survival of germinants (/year)	0.55	0.78*	0.72	0.78*
Subalpine fir	Nat. germinants (/m^2)	0.3	2.1*	0.8	2.1*
	Germinants from seed (%)	2.2	8.7*	3.0	8.7*
	2-yr survival of germinants (/year)	0.62	0.85*	0.68	0.85*

Sources: germinants: Doney and Lloyd (unpublished report, 2000); advanced regeneration: Huggard and Klenner (unpublished data, 2003)

* 2 × 4 m scalped plots are assumed to represent both mounds and scalped site preparation. Longer-term success of natural regeneration may differ between mounded and scalped sites.

Natural regeneration

Advanced regeneration, most of which was in the individual tree selection and uncut treatments, was not affected by mounding, but was nearly eliminated by burning and scalping (Table 2). As well as providing future crop trees, advanced regeneration helps improve habitat structure in managed stands.

Ingress of natural germinants of both tree species was closely tied to exposure of mineral soil. The relatively light burns allowed only a few natural germinants; almost none occurred in the undisturbed no-treatment sites (Table 2). Those few that were found occurred predominantly on CWD. The germination rate of planted seeds was much higher on mineral soil than on other sites. Occurrence of pathological seed fungi is very high in forest floor litter at the site, intermediate in CWD, and low in mineral soil (Zhong and van der Kamp 1999).

Experiments using mesh to protect planted seeds also showed that seed predation is high at the site, with ants likely an important factor. Ants arrived at the site only with harvesting, and are most abundant in burned areas in openings (Table 5). These factors together have resulted in few natural germinants, except on exposed mineral soil, despite high seed production (ranging from 29 to 123 seeds/m^2 per year [Huggard and Vyse 2002a]).

Initial survival of natural germinants was considerably higher in mineral soil than in burned or undisturbed sites (Table 2). However, yearly survival is still quite low, even on suitable sites. Longer-term monitoring will be required to assess the eventual contribution of natural regeneration to future crops trees of either species. Nevertheless, seedfall is high within 20 m of retained trees, suggesting good potential for natural regeneration to meet regeneration objectives in small patch cuts with some mechanical exposure of mineral soil.

Soil chemistry and temperature

The scalped sites showed the greatest and most significant changes in soil nitrogen of all treatments, as a result of the loss of forest floor and mineral soil. Mounding may reduce nitrogen in the forest floor and increase it in the mineral soil through mixing. Concentrations of mineralized nitrogen were about five times as high in the forest floor as in the mineral soil. Mineralized nitrogen is known to rise substantially in harvested areas, and at Sicamous Creek this effect has persisted for at least six years. In the mineral soil, mineralized nitrogen levels were higher in the no-treatment and burned treatments than within a mound or in the scalped treatment (Table 3), probably because mounds include some sub-soil with little organic matter, and scalped soils have little organic matter. In the forest, only the burned treatment led to higher levels of mineralized nitrogen. Overall, the modestly higher levels of mineralized nitrogen in the no-treatment and burned treatments are more likely to benefit tree growth than to cause concern for long-term nutrient loss through leaching.

Carbon:nitrogen ratios and other nutrients in the mineral soil showed relatively little change with site preparation. Some nutrients, such as phosphorus, increased slightly with burning and decreased in the scalped treatments, reflecting changes in the available organic material (Table 3). Calcium and other cations decreased with increasing intensity of site preparation, corresponding to a small increase in pH. These changes are unlikely to result in substantial biological effects, or to create long-term concerns about nutrient balances. Feller (unpublished report, 1994) similarly concluded that site preparation, except for intensive burns, had relatively minor effects on nutrient budgets compared to harvesting.

TABLE 3 *Soil chemistry and temperature responses by harvest and site preparation treatments*

Variable	Harvest treatment	No treatment	Mound	Burn	Scalp
N (forest floor) (g/kg)	All	13.9	12.4	12.6	(0)
N (mineral soil) (g/kg)	All	2.1	2.6	2.4	1.9
Mineralized N (µg/g)*	Openings	19.2	9.1	15.5	7.8
	Uncut forest	9.2	7.3	19.5	4.7
C/N ratio	All	21.8	21.6	21.3	22.3
Ca (mg/kg)	All	556.7	474.3	446.3	387.7
P (mg/kg)	All	7.2	7.0	8.7	5.5
Soil temp. (15 cm, Aug.) (°C)	0.1, 1, 10 ha	10.1	11.4	11.6	11.3
	Individual tree selection, uncut forest	8.7	9.9	8.9	9.8
Soil temp. (1 cm, Sept.) (°C)	All	6.7	8.3	7.6	8.0
Soil temp. (15 cm Sept.) (°C)	All	5.2	4.6	4.7	4.8

Sources: Hope et al. (unpublished report, 2002); Bissonette (unpublished report, 2000)
* All chemical variables from mineral soil except where noted.
* The observed increase in mineralized N is considered a positive effect as a fertilizer for tree growth, but increased nutrient losses from leaching may be a long-term concern.

In openings, soil temperature at 15-cm depth in August increased in the three site preparation treatments compared to the areas of no treatment. This reflects increased absorption of heat by the exposed mineral soil and black, burned litter. A similar pattern was seen in the harvest treatments with some canopy cover, except that burned sites did not differ from undisturbed areas. Lighter burns and less direct radiation probably explain this difference. In September, surface temperatures showed a similar pattern across treatments, but temperatures at 15 cm were higher in undisturbed sites. This may reflect greater overnight loss of heat from the exposed soils in disturbed sites. A larger increase than 1.5°C was anticipated in the August root-zone temperature. This small change might be due to the limited sampling procedure, but the finding is supported by later, more detailed studies of mound microclimate at Sicamous Creek (Orchansky, unpublished report, 2003).

Vegetation

Vegetation cover was substantially reduced immediately after the site preparation treatments, and the treated plots have since shown different rates of recovery and different species presence (Table 4). Cover layers of shrubs, herbs, and bryophytes were reduced to less than half of their no-treatment levels by mounding. Furthermore, this effect exceeds the actual area of the mounds as a result of damage caused by the tracks of the mounding machine. The burns, although relatively light, reduced all three cover layers to about one-third of the no-treatment levels, while the scalps eliminated most vegetation. Ground lichens such as Cladonia also showed substantial decreasing abundance with increasing intensity of site preparation.

In the no-treatment plots, herb and bryophyte layers increased through year 4, as part of an ongoing vegetation response to the harvesting. Also, in the other site preparation plots, herb and bryophyte cover recovered quickly. Shrub layers, on the other hand, recovered much more slowly from the damage experienced during site preparation. Damaged rhododendron, in particular, grew little. Black huckleberry and oval-leaved blueberry plants did respond to site preparation, exhibiting considerably higher growth rates in the burned

areas, and moderate growth in the scalps. Although huckleberry and blueberry shrubs have value to wildlife species as forage and for berries, they remain a relatively minor component of shrub cover. The persistent reduction of shrub cover as a result of harvesting (Huggard and Vyse 2002a), which has a negative effect on wildlife, seems to be exacerbated by even a spot selection site preparation like mounding.

Many individual herb species responded the same way to site preparation as did overall herb cover, but a few showed unique responses. Mitrewort, for example, is generally reduced by harvesting, but it showed a positive response to burning. Fireweed, which was almost absent from the site before harvest, has colonized rapidly in the burned plots, and to a lesser extent in the scalps. It is one of the vegetation species at the site that is tall and dense enough to potentially compete with planted seedlings, although competition effects are not yet apparent. Small-flowered woodrush is another previously rare species that has benefited from disturbance, but it is found predominantly on the mineral soil of the scalped treatment and locally on mounded areas. The two main genera of mosses followed the same pattern of recovery as moss cover overall, but juniper haircap moss responded similarly to woodrush, favouring exposed mineral soil.

Feller (unpublished report, 1994) found similar changes in cover layers, recovery rates, and altered species composition in comparisons of operational site preparation in other ESSF areas. Observations of old site preparation cutblocks near Sicamous Creek also suggest that vegetation differences between burned and mechanically treated sites persist through the early-seral stand phases. The presence of fewer pioneer species and some undisturbed areas of vegetation where mounding was used will probably encourage the most rapid return to pre-disturbance vegetation communities in this treatment.

Coarse woody debris and animals

In addition to vegetation cover discussed above, coarse woody debris is another important wildlife habitat attribute influenced by site preparation.

Hard CWD was not affected by mounding and may have increased slightly in the light burns as residual trees were damaged and fell (Table 5). Soft CWD, however, was substantially reduced by mounding, because it was crushed by the excavator. From the perspective of regeneration sites, the loss of suitable CWD is more than compensated for by the exposure of better mineral soil sites during mounding. However, this loss of CWD could have negative effects on the many animal species associated with decaying logs. A small reduction in soft CWD in burned areas may have been due to the burning, or to mechanical damage during ignition.

Scalping removed almost all CWD, as intended. Even less drastic mechanical site preparation, such as disc-trenching, can cause similar reductions, particularly because damaged pieces decay more rapidly.

Animal responses to the treatments also varied:

- Mites were reduced to one-third abundance where the forest was burned. This may later affect decomposition and nutrient processes (Table 5). However, mite abundance increased somewhat in mineral soil in the more disturbed treatments.
- Harvestmen ("daddy-long-legs") increased in the treated plots, particularly scalps, where these active hunters probably benefited from increased surface temperatures and simpler substrates for movement. However, this effect lasted for only one year. In following years, harvestmen abundance was equal across treatments.
- In harvested areas, centipedes increased in burns, but decreased slightly in mechanical site treatments, probably reflecting changes in prey availability for these hunting animals.
- True bugs, which are plant-feeding insects, showed a huge positive response to burning. This is probably the result of colonization by

TABLE 4 *Vegetation at year 1 and 4 after site preparation by site preparation treatment*

Variable	Year	No treatment	Mound	Burn	Scalp
Total cover (%)	1	45.0	21.0	13.5	5.5
	4	62.3	42.0	39.5	34.0
Shrub cover (%)	1	14.3	6.6	3.7	0.6
	4	12.2	6.8	6.1	1.5
Herb cover (%)	1	22.9	10.2	7.0	3.9
	4	37.9	27.7	28.1	23.0
Bryophyte cover (%)	1	7.3	3.6	2.9	0.6
	4	11.7	7.1	5.0	8.3
Cladonia (class: 0–3) (%)	4	1.8	1.3	0.7	0.4
Huckleberry growth (%)	1–4	-2.2	-3.4	128.6	60.0
Mitrewort cover (%)	4	1.8	2.0	3.3	1.6
Fireweed cover (%)*	4	1.0	1.3	6.2	2.7
Woodrush cover (%)*	4	0.3	1.9	0.5	5.8
Juniper haircap moss cover(%)*	4	0	0.6	0.2	3.3

Source: Miège and Lloyd (unpublished report, 2000)

* These three early seral pioneer species are treated as indicators of disturbance. Hence, lower values are considered better.

species that thrive on recently burned areas. These animals can detect even small burned patches from large distances. Some rarer families of beetles were also found almost exclusively in the burned plots.

- Ants, which are generally associated with disturbed habitats, were absent before harvesting at Sicamous Creek. After harvesting, they were most abundant in burned plots in openings. The large increase in ants is considered a negative effect, as they are the main consumers of conifer seeds, and can exclude many species of insects associated with older, less disturbed forest.
- Rove beetles are an example of a Family associated with older-forest characteristics such as decayed wood and a complex litter layer. In this study, they showed less of a decline than expected in the more severe site preparation plots.
- The two common species of small mammals declined in the site preparation treatments (Table 5). The red-backed vole is considered an indicator of older-forest conditions and has many ecological roles. It showed a particularly sharp decline with site preparation, probably as a result of the decline in its two critical habitat components, shrub cover and decayed CWD. These voles feed primarily on fungi, which were also probably reduced by site preparation.

TABLE 5 *Coarse woody debris, and animal groups, by harvest treatment and site preparation treatment. Blue cells indicate an increase in a biodiversity component of unknown significance. All values (except those for CWD) are relative abundances (100 in treatment where animal is most abundant)*

Variable	Harvest treatment	No treatment	Mound	Burn	Scalp
Hard CWD (m^3/ha)	All	86.9	102.1	115.2	1.2
Soft CWD (m^3/ha)	All	103.0	57.1	71.4	0.6
Mites – forest floor	10 ha	100		37.0	
Mites – mineral soil	10 ha	70.0	60.0	86.7	100
Harvestmen	All (1996)	23.7	37.9	35.6	100
Centipedes	All	63.3	45.6	100	52.8
True bugs	All	2.4	3.2	100	6.4
Ants	All	25.2	37.2	100	49.9
Rove beetles	All	100	92.3	73.3	71.0
Masked shrew	All	100	95.7	59.9	43.0
Red-backed vole	All	100	24.9	24.9	4.7

Sources: CWD: Huggard and Klenner (unpublished data, 2003); mites: Berch (unpublished report, 2002); all other animal groups: Huggard (unpublished report, 2001)

Summary of key results

The site preparation treatments enhanced the survival and growth of planted seedlings of both Engelmann spruce and subalpine fir in the harvested treatments compared to no treatment. Spruce seedlings did best on burned sites.

In the unlogged areas with low canopy light levels, mounding, followed by untreated sites, was best for planted stock.

Germination following natural seedfall of both species was best in the exposed mineral soil of mounds or screefs.

Initial soil chemistry results suggest that some chemical changes were due to site preparation, but that these are likely minor compared to chemical changes following harvesting. Detailed projections of both forest floor and mineral soil nutrients are needed before the long-term consequences of site preparation decisions can be fully understood.

Vegetation cover layers were reduced by about half in mounds and two-thirds in burns, and were nearly eliminated in scalps. Recovery of vegetation cover was occurring somewhat faster in burns than in other treatments. The vegetation communities developing were notably different between the burned and scalped plots.

Soft CWD, an important plant and animal habitat feature and a substrate for natural regeneration, was also reduced by about half in mounded plots. Red-backed voles declined substantially in all site preparation treatments, even the mounds, in response to declines in shrub cover and soft CWD. Burned areas had high densities of ants—a situation with the potential to severely limit natural regeneration and the survival of other insect groups—but the burns also provided habitat for species adapted to such areas (which are becoming rare on the landscape).

Overall, the site preparation alternatives tested had more silvicultural benefits than did no treatment, but they also produced some negative ecological effects. Those negative effects were most severe in the case of scalping, but the impact of mounding was disproportionately high given the small area occupied by mounds. Burns produced a rare habitat type, and may result in more rapid vegetation recovery compared to other treatments.

Management Implications and Limitations

The results of the many studies at Sicamous Creek have several implications for site preparation management:

1. Mounding with an excavator offers early silvicultural benefits compared to no treatment. However, mounding also had several detrimental effects on ecological variables that should not be ignored. Loss of vegetation cover, soft CWD, and several

species of animals is likely due to damage from the excavator making the mounds (rather than damage caused by the area taken up by the mounds). Some of this damage might be mitigated by careful choice of equipment. Smaller machines could be less damaging, or, alternatively, large excavators with a long reach might minimize the area over which the machine has to travel. Excavator operators could also be encouraged to keep the machines on areas already damaged during harvesting, such as defined skid trails, even if this results in less regularly spaced mounds.

2. The fact that some seedlings grew well in the areas that were not site prepared suggests that careful site selection might reduce the need for site preparation, especially on mesic and drier sites. The resulting regeneration will not be evenly spaced, but the resulting small-scale variability itself will offer ecological benefits. Current administrative regulations would have to change before this observation could be acted on.
3. Burning, which has silvicultural advantages and creates unique habitats, should be used more frequently than at present. However, the benefits of burning must be measured against the potential for significant adverse effects, such as the impact of smoke on human health and the cost of escaped fires.
4. Subalpine fir can be regenerated as successfully as Engelmann spruce, given that the conditions needed for successful planted and natural regeneration of both species are similar. Using both of these naturally occurring species to regenerate wetter ESSF stands is not only ecologically beneficial, but also economically less risky in the face of uncertain future wood markets.
5. Abundant seedfall in partial cuts or small-patch systems provides great potential for natural regeneration, but exposed mineral soil is needed to ensure survival and growth of many of the natural seedlings. Without mechanical site preparation, exposed soil from winter harvesting alone is likely to be rare and patchy. Natural germinants do grow on soft CWD, but their survival rate is unclear. Longer-term measurement is needed to determine whether, and under what conditions, these trees survive, and how rapidly they develop.
6. Different responses of the many variables measured in the site preparation treatments at Sicamous Creek show that there is no single optimal treatment to support all forest values. A good rule for maintaining a diversity of forest values is "Don't do the same thing everywhere." The value of variety is already recognized for harvest systems, but the need for variety is less obvious in site preparation decisions, where a single technique tends to be prescribed throughout a forest type. It is recommended that prescribing forest professionals employ mixtures of techniques, especially on mesic sites.
7. The site preparation studies at Sicamous Creek have a number of limitations. The 30 × 30 m experimental plots are small, preventing study of the effects of treatments on larger animals. The plots are also located primarily on mesic sites, so generalization to the many site types in the ESSF areas is uncertain. Most importantly, the results presented cover only the first few years of a long rotation. Projections based on initial results suggest some possible long-term consequences of site preparation decisions, but continued monitoring is required to check these predictions. Because of limited resources for research, operational trials of alternative site preparation techniques are required in a variety of ESSF site types. In keeping with the increasing range of professional responsibilities, the monitoring of operational site preparation trials needs to go beyond a focus on basic silvicultural responses to include a range of ecological values.

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